

Investigation of a SCDMS cryostat with no shield or IVC thermal link at the refrigerator

A SCDMS cryostat design with no thermal link between the shield layer (LN) and the IVC (LHe) layer has been thermally investigated using a modified version of the Matlab thermal model. The dimensions of the layers are similar to that of those in the 3D model created by Ernie Villegas.

The majority of the heat load (~90 %) flowing into the ST, CP, and MC layers is due to conduction thru the graphite tubes. Thus the only way to reduce this heat load without changing the graphite tube structure is to lower the IVC (LHe) layer temperature to reduce the temperature difference between it and the inner layers. The thermal conductivity of the graphite increases as a function of $T^{1.5}$. Of course lowering the shield temperature helps lower the IVC temperature.

The dominant thermal loads on the shield layer are radiation from room temperature and the stripline thermal intercept. If the shield layer is assumed to be well insulated with multi-layer super insulation then the radiation load is about 9 W. The majority of this load occurs at the shield can due to its large surface area. The heat conduction down the 45 strip lines from room temperature to the shield temperature is also about 9 W. Thus the shield heat loads are both near the Estem.

The power generated by the FETs, 0.42 W, dominates the IVC layer heat load. The IVC strip line intercepts about 0.1 W from the shield layer. The IVC heat loads are also in close proximity to the Estem.

With the dominate shield and IVC heat loads near the Estem, it may make sense to pull the heat out thru the Estem instead of conducting it all the way back to the fridge.

The following observations are made based upon 5 different models that investigate using the Estem as the primary shield and IVC heat rejection path:

- (1) A well insulated shield layer gains very little from a thermal connection to the fridge.
- (2) The only significant gain from a thermal connection between the IVC and a fridge cryocooler is the ST heat flow. A small increase in the IVC can temperature sharply increases the ST heat flow due to the conductivity of graphite increasing as a function of $T^{1.5}$.

All copper RRR = 32, file: SCDMS with cryo with mli thicker estem new fig.m

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scdms no fridge shield ivc connection.■
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No. Towers (striplines) = 7 (45);

No shield or IVC fridge link, 4.25" x 0.88" esten

Boxes on right fixed inputs

Graphite $K = 0.004 \text{ T}^{1.5} \text{ W/m-K}^{2.5}$

Cryo S1 cooling power = 18.9382 W

Rjoint SL can-Tower = 3.33e-008 ohms

Cryo S2 cooling power = 0.56461 W

Rjoint CP can-Tower = 4e-006 ohms

Power into LHe can + FETs = $0+0.42$ W;

Rjoint MC can-Tower = 3e-005 ohms

Power into Still can = 0 mW

Icebox

Power into CP can = 0 μ W

Power into MC can = 0 μ W

Cryo

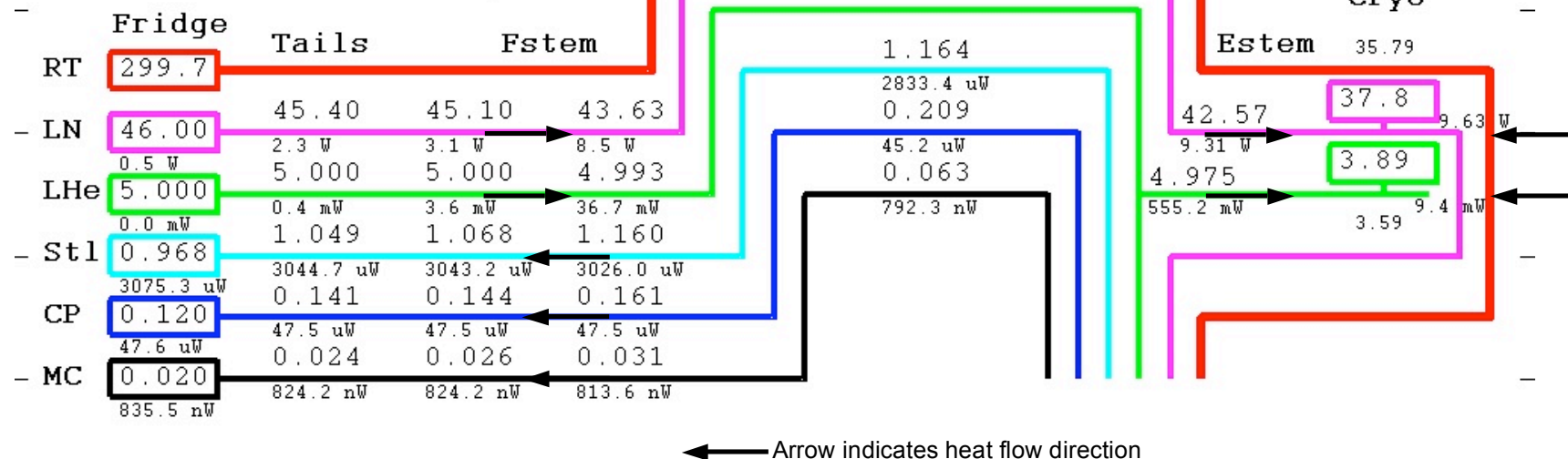


Figure 2: No shield or IVC fridge thermal link to cryostat
Cryocooler linked to shield (LN) and IVC (LHe) only at the estem (right).
Estem shield dimensions: 6.5" OD x 0.5" wall
Estem IVC dimensions: 4.25" OD x 0.88" wall
Fstem shield dimensions: 6.5" OD x 0.5" wall
Fstem IVC dimensions: 5.0" OD x 0.65" wall
All copper RRR = 32, file: scdms no fridge shield ivc connection.m

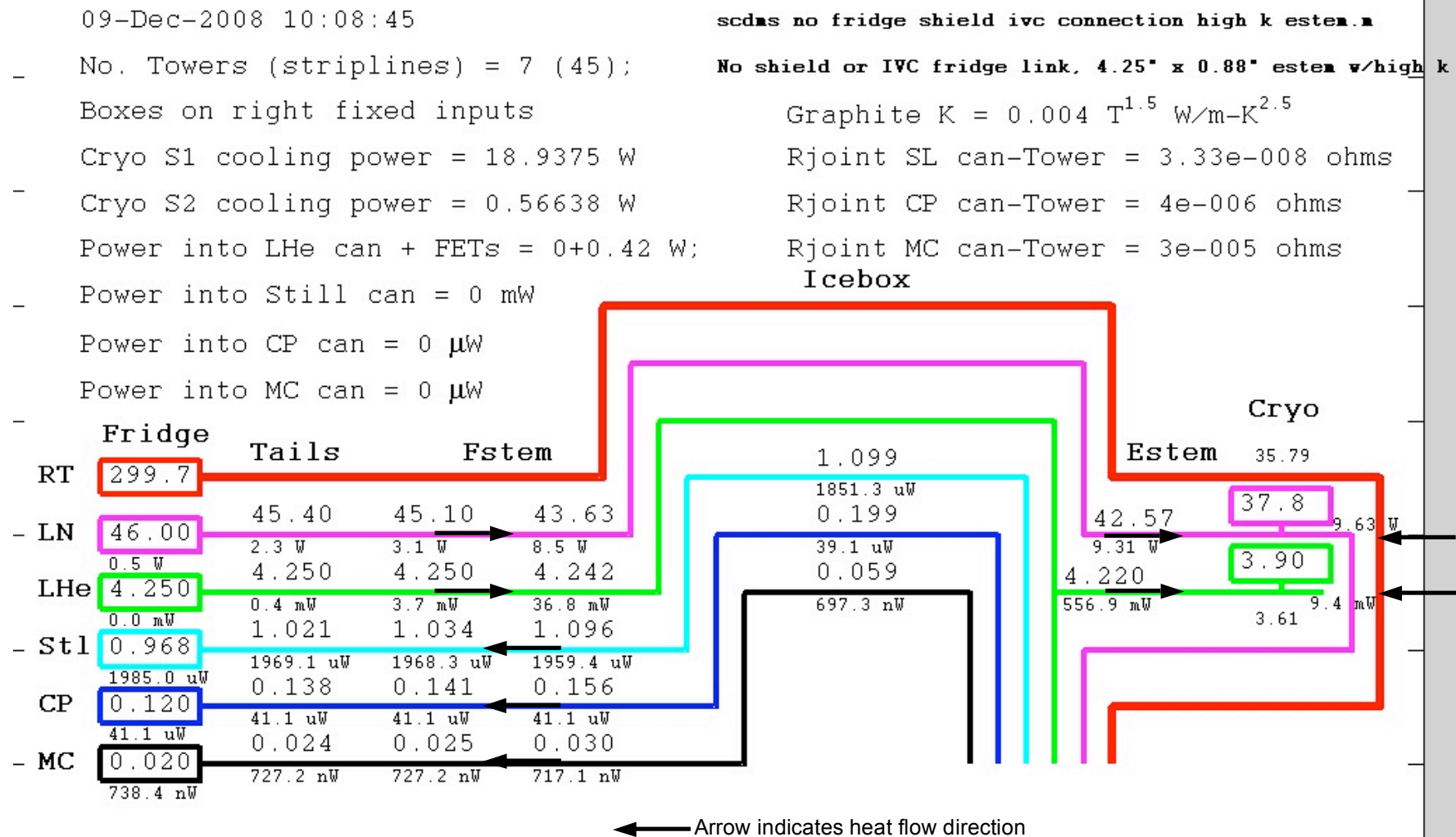


Figure 3: No shield or IVC fridge thermal link to cryostat, with annealed Cu Estem IVC layer

Cryocooler linked to shield (LN) and IVC (LHe) only at the estem (right).

Estem shield dimensions: 6.5" OD x 0.5" wall

Estem IVC dimensions: 4.25" OD x 0.88" wall

Fstem shield dimensions: 6.5" OD x 0.5" wall

Fstem IVC dimensions: 5.0" OD x 0.65" wall

Fstem copper RRR = 32 & Estem IVC layer (Fstem still RRR = 32) copper RRR = 635, file: scdms_no_fridge_shield_ivc_connection_high_k_estem.m

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scdms no fridge shield ivc connection thicker estem.m

No. Towers (striplines) = 7 (45);

No shield or IVC fridge link, 5.0" x 1.5" estem

Boxes on right fixed inputs

Graphite $K = 0.004 T^{1.5} \text{ W/m-K}^{2.5}$

Cryo S1 cooling power = 18.9375 W

Rjoint SL can-Tower = $3.33\text{e-}008$ ohms

Cryo S2 cooling power = 0.56585 W

Rjoint CP can-Tower = $4\text{e-}006$ ohms

Power into LHe can + FETs = 0+0.42 W;

Rjoint MC can-Tower = $3\text{e-}005$ ohms

Power into Still can = 0 mW

Icebox

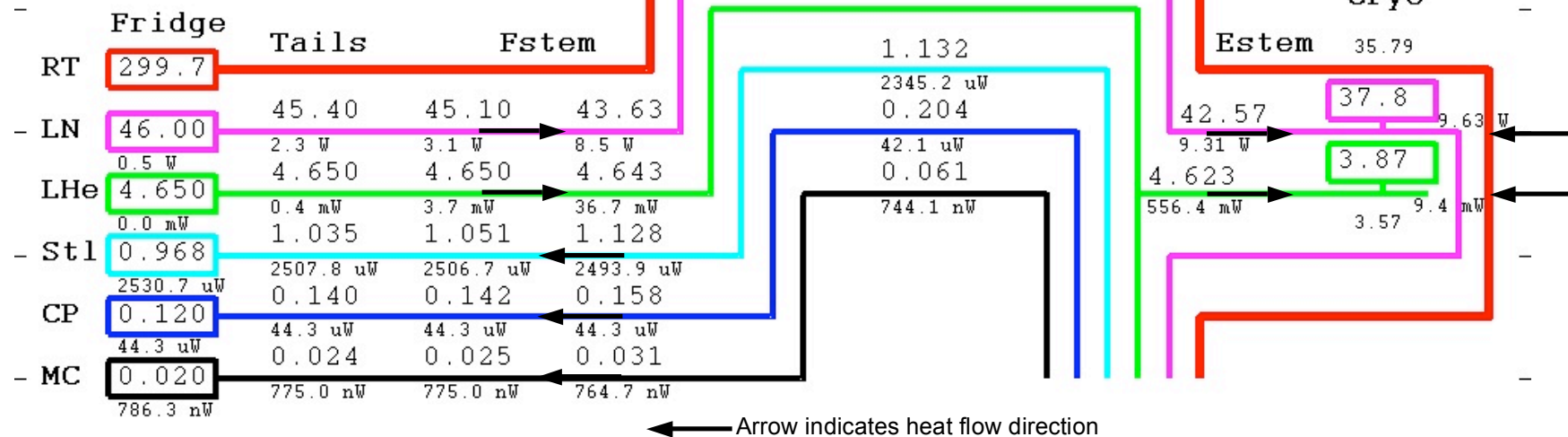
Power into CP can = 0 μW Power into MC can = 0 μW 

Figure 4: No shield or IVC fridge thermal link to cryostat, very thick Estem
Cryocooler linked to shield (LN) and IVC (LHe) only at the estem (right).

Estem shield dimensions: 6.5" OD x 0.5" wall

Estem IVC dimensions: 5.0" OD x 0.15" wall

Fstem shield dimensions: 6.5" OD x 0.5" wall

Fstem IVC dimensions: 5.0" OD x 1.5" wall

All copper RRR = 32, file: scdms_no_fridge_shield_ivc_connection_thicker_estem.m

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09-Dec-2008 14:09:10      scdms no fridge shield connection.m
- No. Towers (striplines) = 7 (45);      No shield fridge link, 4.25" x 0.88" estem
Boxes on right fixed inputs      Graphite K = 0.004 T1.5 W/m-K2.5
Cryo S1 cooling power = 18.9379 W      Rjoint SL can-Tower = 3.33e-008 ohms
- Cryo S2 cooling power = 0.39883 W      Rjoint CP can-Tower = 4e-006 ohms
Power into LHe can + FETs = 0+0.42 W;      Rjoint MC can-Tower = 3e-005 ohms
- Power into Still can = 0 mW      Icebox
Power into CP can = 0 μW
Power into MC can = 0 μW

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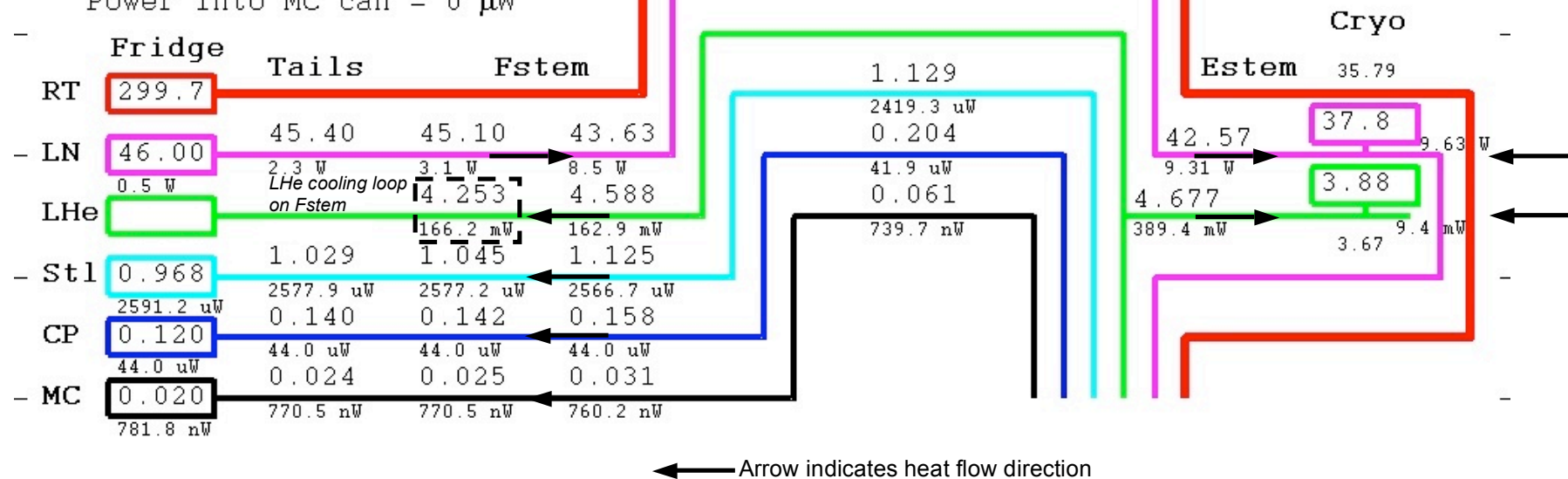


Figure 5: No shield (LN) fridge thermal link to cryostat, IVC (LHe) linked to LHe coil on Fstem set to 4.25 K
 Cryocooler linked to shield (LN) and IVC (LHe) only at the estem (right).
 Estem shield dimensions: 6.5" OD x 0.5" wall
 Estem IVC dimensions: 4.25" OD x 0.88" wall
 Fstem shield dimensions: 6.5" OD x 0.5" wall
 Fstem IVC dimensions: 5.0" OD x 0.65" wall
 All copper RRR = 32, file: scdms_no_fridge_shield_connection.m

Table 1: Summary of the 5 cases.

Figure #	Fstem shield & IVC cryocooler connection	Estem shield & IVC cryocooler connection	Fstem IVC LHe loop	Estem 4.25" OD x 0.88" wall	Estem 5.0" OD x 1.5" wall	Estem IVC Cu RRR = 32	Estem IVC Cu RRR = 635	MC heat flow nW at fridge	CP heat flow μ W at fridge	ST heat flow μ W at fridge	Estem cryocooler stage one W	Estem cryocooler stage 2 mW	MC can temp K	CP can temp K	ST can temp K	IVC can temp K	LN can temp K
1	✓	✓		✓		✓		748	42	2087	10.1	318	0.060	0.200	1.105	4.30	36.90
2		✓		✓		✓		836	48	3075	18.9	565	0.063	0.209	1.164	4.98	42.57
3		✓		✓			✓	738	41	1985	18.9	566	0.059	0.199	1.099	4.22	42.57
4		✓			✓	✓		786	44	2531	18.9	565	0.061	0.204	1.132	4.62	42.57
5		✓	✓	✓		✓		782	44	2591	18.9	389	0.061	0.204	1.129	4.68	42.57